

Claims

1. A composition comprising:
 - a first component comprising a photocatalyst that photocatalyzes a reaction of a reactant to a product;
 - a second component that has a chemical formula different from the chemical formula of said first component, and that chemically bonds to the reactant or to an intermediate of the reaction, said second component being present in an amount sufficient to enhance the reaction; and
 - a third component that has a chemical formula different from the chemical formulas of said first and second components, and that chemically adsorbs and holds hydroxyl groups, said third component being present in an amount sufficient to impart hydrophilicity to said composition.
2. A composition as defined in claim 1 having the form of a layer on a substrate.
3. A composition as defined in claim 2 wherein the substrate is selected from the group consisting of ceramic, resin, metal, glass, earthenware, wood, calcium silicate board, concrete board, cement board, cement extruded board, plaster board, and autoclave light-weight concrete board.
4. A composition as defined in claim 2 wherein said layer is bonded to the substrate by a binder.
5. A composition as defined in claim 1 wherein said third component is present in an amount effective to achieve a hydrophilicity level corresponding to a contact angle of not more than about 20 degrees.
6. A composition as defined in claim 1 wherein said first, second and third components are metal oxides.
7. A composition as defined in claim 1 wherein said second component is an acidic metal oxide.
8. A composition as defined in claim 1 wherein said second component is a basic metal oxide.
9. A composition as defined in claim 1 wherein said second component is an amphoteric metal oxide.
10. A composition as defined in claim 1 wherein said second component is selected from the group consisting of Al_2O_3 , BaO , CaO , K_2O , MgO , Na_2O , P_2O_5 , Rb_2O , SnO , SnO_2 , SrO and ZnO .
11. A composition as defined in claim 1 wherein said third component is selected from the group consisting of Al_2O_3 , GeO_2 , SiO_2 , ThO_2 , ZnO and ZrO_2 .

12. A composition as defined in claim 1 wherein said third compound has a heat of wetting higher than that of said photocatalyst.

13. A composition as defined in claim 1 wherein said components are dispersed in a glaze.

14. A composition as defined in claim 13 wherein the glaze is feldspar.

15. A composition as defined in claim 1 wherein said components are dispersed in a paint.

16. A composition as defined in claim 1 further comprising a fourth component comprising an antimicrobial metal present in an amount sufficient to achieve antimicrobial activity.

17. A composition as defined in claim 16 wherein said fourth component is chosen from the group consisting of Al, Ag, Au, Ca, Cr, Co, Cu, Fe, Mg, Ni, Pd, Pt, Rh, Ru and Zn.

18. A composition as defined in claim 16 wherein said fourth component is included in said composition through the process of:

combining an aqueous salt solution containing ions of said antimicrobial metal with said first photocatalyst; and

irradiating said aqueous salt solution with ultraviolet light to photoreduce said ions to a metallic form adhering to said composition.

19. A method for combining an antimicrobial metal with a photocatalyst, comprising the steps of:

forming a mixture of a sol of photocatalyst particles and an aqueous salt solution containing ions of said antimicrobial metal; and

irradiating said mixture with ultraviolet light to photoreduce said ions to a metallic form adhering to said photocatalyst particles, while said particles are suspended in said mixture.

20. A method as defined in claim 19 further comprising the steps of:

dispersing among said photocatalyst particles a second component that has a chemical formula different from the chemical formula of said first component, and that chemically bonds to a reactant or to an intermediate of a reaction that is photocatalyzed by said photocatalyst particles, said second component being present in an amount sufficient to enhance the reaction; and

dispersing among said photocatalyst particles a third component that has a chemical formula different from the chemical formulas of said first and second components, and that chemically adsorbs and holds hydroxyl groups, said third component being present in an amount sufficient to impart hydrophilicity to said composite.

21. A composite material for use in air purification in an environment where the contact of said composite material with water can be expected, said composite material comprising at least a substrate and a surface layer, said surface layer being hydrophilic and self-cleanable, said surface layer comprising:

a component (i) comprising a photocatalyst which functions as a catalyst upon exposure to light;

a component (ii) comprising at least one metal oxide selected from the group consisting of Al_2O_3 , ZnO , SrO , BaO , MgO , CaO , Rb_2O , Na_2O , K_2O , and P_2O_5 ; and

a component (iii) comprising at least one metal oxide selected from the group consisting of SiO_2 , ZrO_2 , GeO_2 , and ThO_2 .

22. A composite material according to claim 21, which satisfies $a/(a+b)$ of about 0.0001 to about 0.8, wherein a represents the weight of the metal oxide as the component (ii) and b represents the weight of the photocatalyst as the component (i).

23. A composite material according to claim 21 or 22, wherein the photocatalyst as the component (i) and the metal oxide as the component (ii) are contained in the form of particles having a diameter of about 0.005 to about 0.5 microns.

24. A composite material according to claims 21, which further comprises a component (iv) which is at least one antimicrobial metal selected from the group consisting of zinc, silver, and copper, the antimicrobial metal as the component (iv) being supported on the photocatalyst as the component (i).

25. A composite material according to claim 21, wherein at least one metal selected from the group consisting of silver, copper, palladium, iron, nickel, chromium, cobalt, platinum, gold, rhodium, and ruthenium is contained as the component (iv) in an amount effective for improving the oxidative degradation activity.

26. A composite material according to claim 21, wherein at least one metal selected from the group consisting of lithium, calcium, magnesium, and aluminum is contained as the component (iv) in an amount effective for improving the hydrophilicity.

27. A composite material according to claim 24, which satisfies c/d of about 0.00001 to about 0.05, wherein c represents the weight of the component (iv) and d represents the weight of the photocatalyst as the component (i).

28. A composite material according to claim 21, wherein the surface layer has a geometry satisfying any one of the following requirements (1) and (2):

(1) thickness of surface layer is about 0.01 to about 3.0 microns; and

(2) difference in color ΔE of the surface layer between before ultraviolet irradiation and after ultraviolet irradiation of the surface layer, with a 1% silver nitrate solution deposited thereon, for 5 min at an ultraviolet intensity on the surface layer of 1.2 mW/cm^2 , is 1 to 50.

29. A composite material according to claim 21, wherein a binder is interposed between the substrate layer and the surface layer.

30. A composite material according to claim 29, wherein the binder is polymerizable or meltable below a temperature at which the substrate is deformed, to fix the surface layer onto the substrate.

31. A composite material according to claim 30, wherein the binder is a glaze or a paint.

32. A composite material according to claim 21, wherein the substrate is a tile.

33. A composite material according to claim 21, wherein the substrate is an earthenware, a wood, a calcium silicate material, concrete, a cement board, a cement extruded board, a plaster board, or an autoclave light-weight concrete board.

34. A composite material according to claim 21, wherein an antimicrobial metal or a metal compound is anchored on the surface of the surface layer.

35. A formulation capable of forming the surface layer of the composite material according to claim 21, wherein said formulation comprises:

a component (i) comprising a photocatalyst which functions as a catalyst upon exposure to light;

a component (ii) comprising at least one metal oxide selected from the group consisting of Al_2O_3 , ZnO , SrO , BaO , MgO , CaO , Rb_2O , Na_2O , K_2O , and P_2O_5 ; and

a component (iii) comprising at least one metal oxide selected from the group consisting of SiO_2 , Al_2O_3 , ZrO_2 , GeO_2 , and ThO_2 .

36. A formulation according to claim 35, which satisfies $a/(a+b)$ of about 0.0001 to about 0.8, wherein a represents the weight of the metal oxide as the component (ii) and b represents the weight of the photocatalyst as the component (i).

37. A formulation according to claim 35 or 36, wherein the photocatalyst as the component (i) and the metal oxide as the component (ii) are contained in the form of particles having a diameter of about 0.005 to about 0.5 microns.

38. A formulation according to claim 35, which further comprises a component (iv) comprising at least one antimicrobial metal selected from the group consisting of zinc, silver, and copper, the antimicrobial metal as the component (iv) being supported on the photocatalyst as the component (i).

39. A formulation according to claim 35, wherein at least one metal selected from the group consisting of silver, copper, palladium, iron, nickel, chromium, cobalt, platinum, gold, rhodium, and ruthenium is contained as the component (iv) in an amount effective for improving the oxidative degradation activity of a surface formed by the formulation.

40. A formulation according to claim 35, wherein at least one metal selected from the group consisting of lithium, calcium, magnesium, and aluminum is contained as the component (iv) in an amount effective for improving the hydrophilicity of a surface formed by the formulation.

41. A formulation according to claim 35, which satisfies c/d of about 0.00001 to about 0.05 wherein c represents the weight of the component (iv) and d represents the weight of the photocatalyst as the component (i).

42. A process for producing the composite material according to claim 21, said process comprising at least the steps of:

providing the formulation according to claim 35 or a dispersed sol with said formulation dispersed therein;

applying the formulation or the dispersed sol onto the substrate; and

drying or heating the substrate with the formulation or the dispersed sol applied thereonto, thereby forming a surface layer.

43. A process according to claim 42, wherein the formulation or the dispersed sol is applied onto the substrate by putting, coating, or printing.

44. A process for producing the composite material according to claim 21, said process comprising at least the steps of:

providing the formulation according to claim 35 or a dispersed sol with said formulation dispersed therein;

forming a binder layer on the substrate;

applying the formulation or the dispersed sol onto the binder layer; and

drying or heating the substrate with the formulation or the dispersed sol applied thereonto, thereby forming a surface layer.

45. A process according to claim 44, wherein:
the binder layer is formed of a glaze; and
the substrate with the formulation or the dispersed sol applied thereonto is heated at a temperature that is 30 to 300°C above the softening temperature of the glaze and below a temperature at which the substrate is deformed, thereby forming a surface layer.

46. A process according to claim 45, wherein the temperature is 30 to 300°C above the softening temperature of the glaze and below a temperature at which the substrate is deformed, and is about 150 to about 1,300°C.

47. A process according to claim 42, which further comprises, subsequent to the step of forming the surface layer, the step of coating a solution containing an antimicrobial metal or a metal compound dispersed therein on the surface of the surface layer and the step of anchoring the metal or metal oxide on the surface of the surface layer.

48. A process according to claim 42, which further comprises, after the application of the formulation or the dispersed sol, the step of coating a solution containing an antimicrobial metal or a metal compound dispersed therein.

49. A process according to claim 42, which further comprises, subsequent to the step of forming the surface layer, the step of coating an aqueous solution containing ions of a metal having antimicrobial activity on the surface of the surface layer and the step of irradiating the surface layer with ultraviolet light, whereby the metal is supported or fixed on the photocatalyst in the surface layer through photoreduction.

50. A process for producing the formulation according to claim 38 comprising the steps of:

providing a sol containing at least the component (i) dispersed therein; and
mixing the sol with the component (iv) and supporting the component (iv) on the surface of the photocatalyst.

51. A process according to claim 50, wherein the component (iv) is supported on the surface of the photocatalyst by coprecipitation of a salt of the component (iv) and the photocatalyst.

52. A process according to claim 50, wherein the component (iv) is supported on the surface of the photocatalyst by applying ultraviolet light to a mixture of the sol with the component (iv) to support the component (iv) on the surface of the photocatalyst through photoreduction of the photocatalyst.

53. A method for cleaning air, comprising the steps of:
contacting air with the surface of a composite material which is exposed to light; and
contacting the surface of the composite material with water, said composite material comprising at least a substrate and a surface layer, said surface layer being hydrophilic and self-cleanable, said surface layer comprising:

 a component (i) comprising a photocatalyst which functions as a catalyst upon exposure to light;

 a component (ii) comprising at least one metal oxide selected from the group consisting of Al_2O_3 , ZnO , SrO , BaO , MgO , CaO , Rb_2O , Na_2O , K_2O , and P_2O_5 ; and

 a component (iii) comprising at least one metal oxide selected from the group consisting of SiO_2 , ZrO_2 , GeO_2 , and ThO_2 .

54. A method according to claim 53, wherein the composite material satisfies $a/(a+b)$ of about 0.0001 to about 0.8, wherein a represents the weight of the metal oxide as the component (ii) and b represents the weight of the photocatalyst as the component (i).

55. A method according to claim 53, wherein the photocatalyst as the component (i) and the metal oxide as the component (ii) are contained in the form of particles having a diameter of about 0.005 to about 0.5 microns.

56. A method according to claim 53, wherein the composite material further comprises a component (iv) comprising at least one antimicrobial metal selected from the group consisting of zinc, silver, and copper, the antimicrobial metal as the component (iv) is supported on the photocatalyst as the component (i).

57. A method according to claim 53, wherein at least one metal selected from the group consisting of silver, copper, palladium, iron, nickel, chromium, cobalt, platinum, gold, rhodium, and ruthenium is contained as the component (iv) in an amount effective for improving the oxidative degradation activity.

58. A method according to claim 53, wherein at least one metal selected from the group consisting of lithium, calcium, magnesium, and aluminum is contained as the component (iv) in an amount effective for improving the hydrophilicity.

59. A method according to claim 56, wherein the composite material satisfies c/d of about 0.00001 to about 0.05 wherein c represents the weight of the component (iv) and d represents the weight of the photocatalyst as the component (i).

60. A method according to claim 53, wherein the surface layer has a geometry satisfying any one of the following requirements (1) and (2):

(1) thickness of the surface layer is about 0.01 to about 3.0 microns; and

(2) difference in color ΔE of the surface layer between before ultraviolet irradiation and after ultraviolet irradiation of the surface layer, with a 1% silver nitrate solution deposited thereon, for 5 min at an ultraviolet intensity on the surface layer of 1.2 mW/cm^2 , is 1 to 50.

61. A method according to claim 53, wherein the composite material has a binder which is interposed between the substrate and the surface layer.

62. A method according to claim 61, wherein the binder is polymerizable or meltable below a temperature at which the substrate is deformed, to fix the surface layer onto the substrate.

63. A method according to claim 62, wherein the binder is a glaze or a paint.

64. A method according to claim 53, wherein the substrate is a tile.

65. A method according to claim 53, wherein the substrate is an earthenware, a wood, a calcium silicate material, concrete, a cement board, a cement extruded board, a plaster board, or an autoclave light-weight concrete board.

66. A method according to claim 53, wherein the composite material has an antimicrobial metal or a metal compound which is anchored on the surface of the surface layer.